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A HYBRID APPROACH OF THE PRODUCT IMAGE DESIGN OF TRAIN SEATS BASED ON KANSEI ENGINEERING THEORY

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Abstract. *With the rapid development of industrial technology, product design has changed from "production-oriented" to "user-oriented". Aiming at the user-oriented product image design system, this paper proposes a hybrid research method of product image design system based on the theoretical framework of Kansei engineering by the experimental study of train seat form and color design. Firstly, GRA-Fuzzy logic sub-model for product form and color design was constructed objectively. Next, based on GRA-Fuzzy logic sub-model of train seat image design, a hybrid model of product image design is obtained by combining Delphi method and utility optimization model. Finally, a decision-making optimization system of product image design is established. The experimental result shows that the hybrid model performs well in predicting the product image, which is conducive to promoting and optimizing the process of product image design based on user perception.*

Keywords: Hybrid model, Kansei engineering, Product image, Form design, Color design, Train seats

1. **Introduction.** The product design trend development will affect the user's lifestyle, and promote the product design process. With the contemporary design capability growth and user's cognitive improvement, the essential product demand is not only the functional and aesthetic needs, but also the factor that affects the user feeling. The formation of product image comes from user's cognition for the product design [1]. The design elements of product (such as the product form, color, material, texture, and pattern) affecting the product image are taken as the communication symbols between the product and user. Therefore, the product image design process is required to be more efficient, accurate and intelligent.

Kansei engineering is a theory that uses engineering technology to explore the correlation between the perceptual demands of users and design elements of product [2]. It can transform the users' perceptual needs that are difficult to quantify into product design elements as shown in Figure 1. Kansei engineering quantifies the user's perception into design parameters, which helps designers understand the perceptual needs of consumers more comprehensively, and then helps users identify and express their perceptual demands for products. Kansei engineering experiment can optimize and improve product image design process. Therefore, professional designers can design products with different Kansei images, improve users' satisfaction and reduce design costs.

In terms of product image acquisition and analysis methods, Tsutsumi and Sasaki used genetic algorithm to evaluate the aesthetic and economy of form design, neural network

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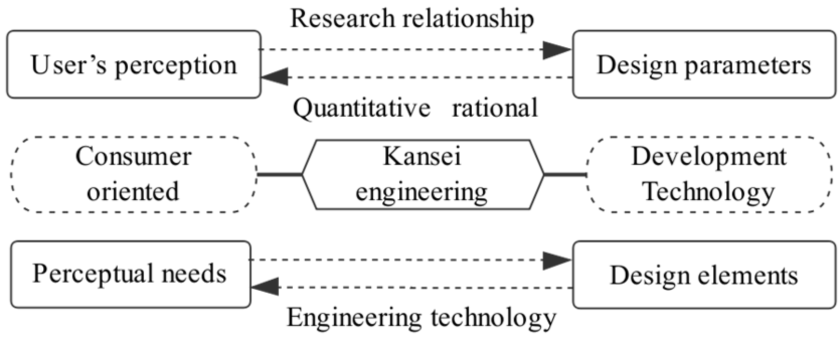


Figure 1. The study of Kansei engineering

algorithm to calculate the perceptual evaluation of questionnaire survey, finite element method to calculate the stress to obtain the economic evaluation, and finally used fuzzy theory to calculate the comprehensive satisfaction [3]; Yan and Ma obtained product perceptual data through semantic differential method, summarized perceptual curve on the basis of semantic scores, gathered product evaluation satisfaction by priority clustering method, and studied user's preferences for product image needs [4].

In research on the correlation between perceptual needs and design elements, Nagamachi constructed the Kansei engineering system based on the relationship between consumers' perceptual needs and design elements [5]; Abubakar and Wang applied the semantic differential method to studying the perceptual image of users associated with design elements, and established the knowledge base after multivariate quantitative analysis [6]; Chen and Chang used mathematical tools to express the appearance of product explicitly, built the corresponding relationship between product Kansei image and design elements, and constructed product image form design system [7].

With regard to user preference, Park and Han constructed a model based on fuzzy rules, and established the modeling variables and user preference of office chair design linked with perceptual satisfaction. The research shows that the fuzzy model based on fuzzy rules has better prediction performance than the traditional regression model [8].

In aspect of design optimization and development prediction, Sasmoko et al. proposed a novel application of self-diagnostics using fuzzy logic for quality improvement [9]; Xiong et al. integrated the Grounded Theory (GT) from the social sciences' domain and the method of multiple attribute decision making from operations research by analyzing their advantages and congruence to create a qualitative-quantitative evaluation model [10]; Lin and Wei focused on users' affective preferences in relation to visual ergonomics to propose a new hybrid user-oriented model using Gray Relational Analysis (GRA), Gray Prediction (GP), and the technique for order preference by similarity to ideal solution [11]; Based on the Kansei engineering theory, the product image plays an important role in the user-oriented design process, and the product form and product color are relative to the product image. In order to satisfy the user perception of the product from design perspective, the two sub-models are developed, namely product image design qualitative decision model and quantitative decision model [12].

As suggested in our previous study, the GRA-Fuzzy logic model can be constructed to determine the value of the Kansei image for a given product, which can help designers focus on the influential design elements with the specific product images [13]. In line with the results of our previous research, we propose a new method that combines Grey Relational Analysis (GRA), GRA-Fuzzy logic theory, Delphi method, utility optimization model and product image design system.

This paper clarifies the proportion of GRA-Fuzzy logic sub-models of product image design elements, and refines the research of product design on influencing total image and sub-image. Then the Kansei image system of train seat is constructed, and the design method of product image innovation system is optimized. It provides a new methodological system for product image innovative design and design evaluation, makes up for the weakness of establishing industrial product Kansei image system in existing product design research, puts forward a more scientific, efficient and intelligent product image design evaluation system, and is also a complement to the theoretical research of industrial design.

In this study, the organization of sections is shown as below. Kansei engineering experimental process is proposed in Section 2. Section 3 represents hybrid research methodology for product image design. Section 4 introduces the experimental study of train seat form and color design. Section 5 describes the research limit and discussion. Section 6 concludes the work in this paper.

2. **Kansei Engineering Experimental Process.** The Kansei engineering experimental process comprises the experimental subject extraction, experimental sample extraction and design element analysis, Kansei word extraction and product Kansei image database. The specific steps of these four phases are described as below.

2.1. **Experimental subject extraction.** Initially, we divided the experimental subjects into four groups, according to the different personal information, travel experience and professional skills. The first group contains expert users, the second group includes general users, the third and fourth groups involve with the professional product form and color designers, respectively, as shown in Figure 2.

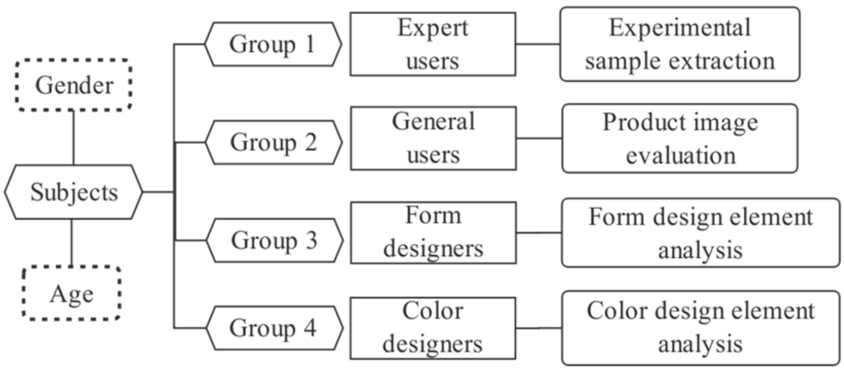


Figure 2. The group overview of experimental subjects

2.2. **Experimental sample extraction and design element analysis.** Then we select the experimental samples and analyze the product elements. The product pictures of various brands and makers are collected widely. Subsequently, the subjects of the first group classify the selected product pictures based on their similarity degree, using the Kawakita Jiro (KJ) method. The KJ method, also known as Affinity Diagram, is a method for establishing an orderly system from chaotic information. This method is devised by Jiro Kawakita for classifying ideas, concepts or objects from brainstorming into several groups, based on their natural relationships [14]. Finally, we perform the clustering analysis and multi-dimensional scale analysis upon the classification result obtained from the subjects of first group. Therefore, the flowchart of experimental sample extraction is illustrated as Figure 3.

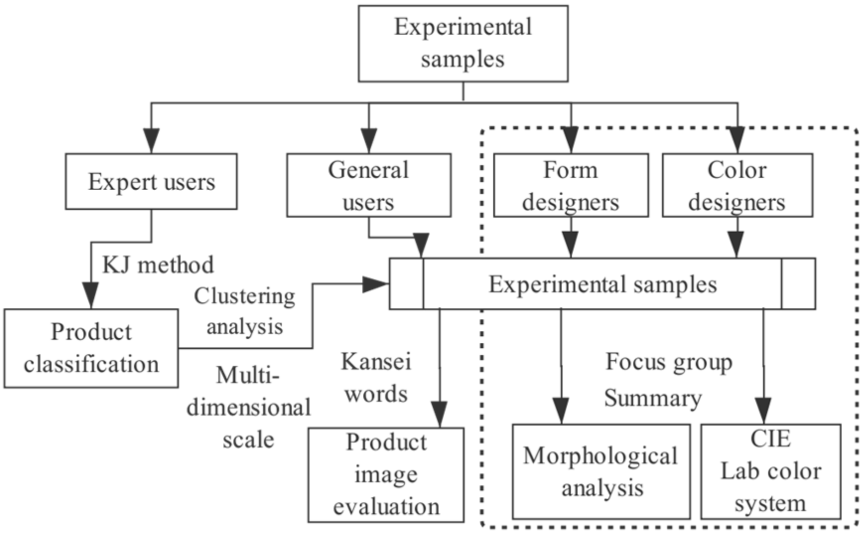


FIGURE 3. The flowchart of experimental sample extraction and design element analysis

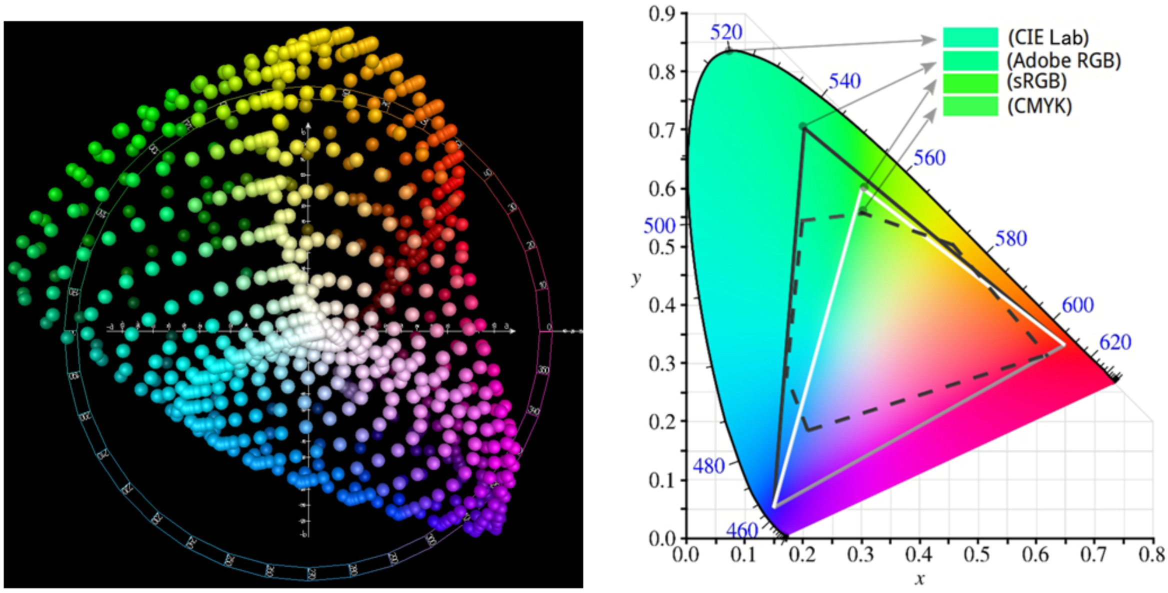
The product design elements of the experimental samples are analyzed. In this paper, the product form and color design are taken as the research objects. Therefore, the morphological analysis is used to extract the form design elements of the experimental samples. The product form designers of the third group are requested to write down the key form elements of the experimental samples individually, according to their professional knowledge and design experience. The subjects of the third group form a focus group to summarize and integrate their analysis results. The morphological analysis results are divided into form characteristics and form relation.

Moreover, the color system of Commission International Eclairage (CIE) Lab is selected because its color space is more uniform and wider than other color systems. The CIE Lab is the color mode based on human visual perception. Figure 4(a) illustrates the color space of CIE Lab. In addition, according to Figure 4(b), the largest horseshoe shaped area shows the CIE Lab space, and the three kinds of polygons present the color space range of Adobe RGB (black line), sRGB (white line) and CMYK (dotted line) color system [15]. The CIE Lab color system not only includes gamut of the above three color systems, but also presents the color that they cannot show. Therefore, the CIE Lab color system is used in the product design color analysis in this paper.

2.3. **Kansei word extraction.** The user's perception for product design can be described by the product image Kansei word pairs. According to the quantitative category, product image can be divided into total image and sub-image, while on the basis of attribute category, it includes main image and secondary image, as shown in Figure 5. The extraction of the representative Kansei word pairs is achieved through collection, evaluation, analysis and determination.

2.4. **Product Kansei image database.** Using the semantic differentials method, the expert users of the first group use seven-point scale to evaluate the product image. The product Kansei image values obtained through the Kansei engineering experiment construct the product Kansei image database, which provides the database support for the construction of product image design hybrid model.

3. **Hybrid Research Methodology for Product Image Design.** This section interprets the GRA-Fuzzy logic model, Delphi method, utility optimization model, eventually



(a) (b)

FIGURE 4. (color online) Comparison of CIE Lab, Adobe RGB, sRGB and CMYK color spaces

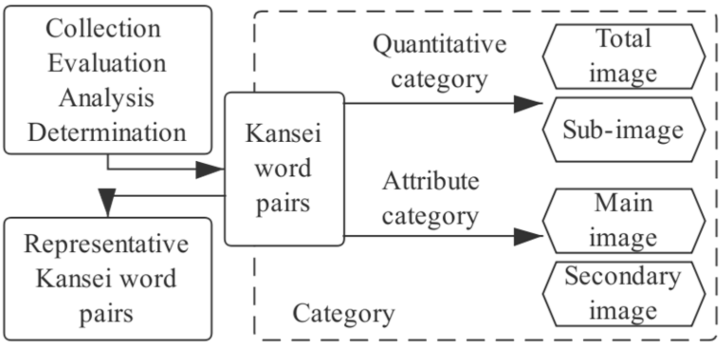


FIGURE 5. The category of Kansei word pairs for product image

creates the hybrid model of product image design and evaluates its performance. To begin with, through the previous Kansei engineering experiment, the product image database is established. Then the GRA-Fuzzy logic model of product image design is constructed, including the form design and color design sub-models. Based on product image design sub-models, the hybrid model is obtained by using Delphi method and utility optimization model. The final stage is the performance evaluation of the hybrid model of product image design.

3.1. **GRA-Fuzzy logic model.** Grey Relational Analysis (GRA) is a method to determine the similarity between two groups of random sequence in grey system [16]. Therefore, the grey correlation coefficient $r(x_0, x_i)$ between the comparison sequence and the reference sequence is usually calculated as follows:

$$r(x_0, x_i) = \frac{1}{n} \sum_{k=1}^{n} r(x_0(k) - x_i(k)), \quad i = 1, 2, \ldots, m \tag{1}$$

The grey correlation coefficients of different design elements are different. If $r(x_0, x_i) > r(x_0, x_j)$, then design element x_i is more relevant to product image than design element x_j. Based on the Kansei image database of each design element affecting the product image, the grey correlation coefficient is used to express the relationship between the product image and design elements. By comparing the numerical value of grey correlation coefficient, the order of the influence degree of different design elements on product image is obtained. The most influential form and color design elements are selected as input linguistic variables, and the corresponding product image as output linguistic variables of GRA-Fuzzy logic model.

Based on GRA-Fuzzy theory, combined with Kansei engineering experiment in Section 2, the construction of GRA-Fuzzy logic model process is shown in Figure 6. First of all, the most influential design elements are selected by GRA, and then the most influential design elements selected by the subjects are taken as input fuzzy sets, along with the evaluated values of product images in Section 2.4 as output fuzzy sets. The triangular

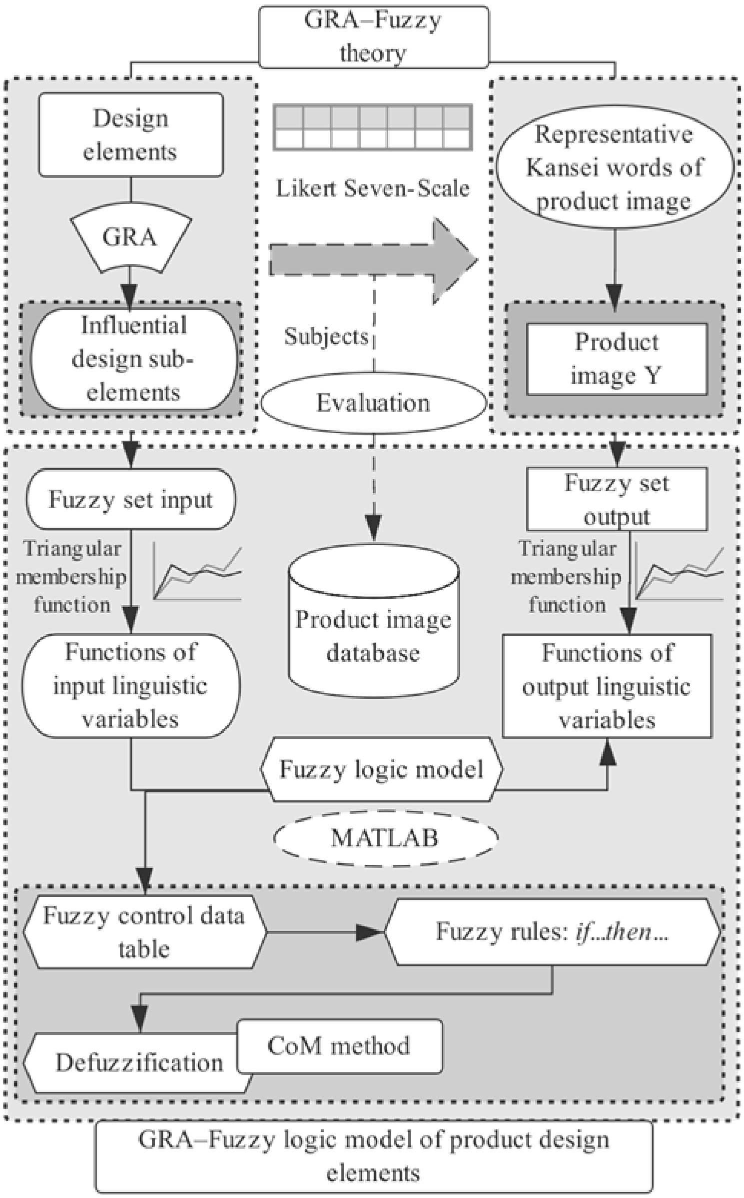


Figure 6. The flowchart of GRA-Fuzzy logic model of product image design

functions of input and output linguistic variables are obtained. Equation (2) shows the membership function $\mu_A(x)$ of a triangular fuzzy number represented by a triple (a, b, c), where a, b, c are real numbers with $a \leq b \leq c$.

$$\mu_A(x) = \begin{cases} 0, & x < a \\ \dfrac{x-a}{b-a}, & a \leq x \leq b \\ \dfrac{x-c}{b-c}, & b \leq x \leq c \\ 0, & x > c \end{cases} \tag{2}$$

Subsequently, by applying the fuzzy logic model in Matlab, the fuzzy control data table and fuzzy rules are constructed. Each fuzzy rule associates the given combination of product design elements with the corresponding value states of the product images. We construct the fuzzy rules with the most influential form and color design elements obtained by GRA for the product images. Defuzzification is the process of converting the membership of the output linguistic variables into specific values, and the defuzzification of fuzzy numbers is usually used by Center of Maximum (CoM) method.

Finally, GRA-Fuzzy logic model of product image design is established to determine the product image values, which assists designers in evaluating the product image design. When product form or color designers input the combination of product design elements, the model can output the value of product image and obtain the numerical state of multiple product images.

3.2. **Delphi method.** Delphi method is a common method in the process of anticipation and decision-making, which is suitable for the application in social investigation and case analysis. The application of Delphi method is to collect and synthesize expert opinions according to pre-set system procedures. After repeated investigation, consultation, modification and conclusion, the experts' views are basically unanimous [17]. These opinions have a certain comprehensive and scientific understanding as the predicted results. The idiographic steps of this method are given in Figure 7.

1) Expert group establishment. The participants of the expert group are determined according to the knowledge domain of project research. The number of experts can be determined by the scale of research and the involved knowledge, usually 10 persons.

2) Research material preparation. According to the prediction content and related requirements of the study, research materials prepared include all project information. Meanwhile every expert is consulted to supplement the specific materials they need.

3) Prediction, feedback and consultation. Each expert puts forward the prediction opinions based on the materials they obtained. The opinions of all experts are collected, summarized, distributed and further modified. It usually takes 3-4 rounds until all experts reach a consensus.

4) Prediction results formation. The experts' opinions are comprehensively processed to form the final prediction results, which can be used as the practical theory and guidance suggestions of the project research.

3.3. **Utility optimization model.** In product design process, it is difficult to use a single index to judge design scheme. For the solution method of multi-objective programming, the utility optimization model can be used by transforming the multi-objective model into the single-objective model which is relatively easy to solve. The basic idea of model is that the programming problem with the objective function can be solved in the corresponding way [18].

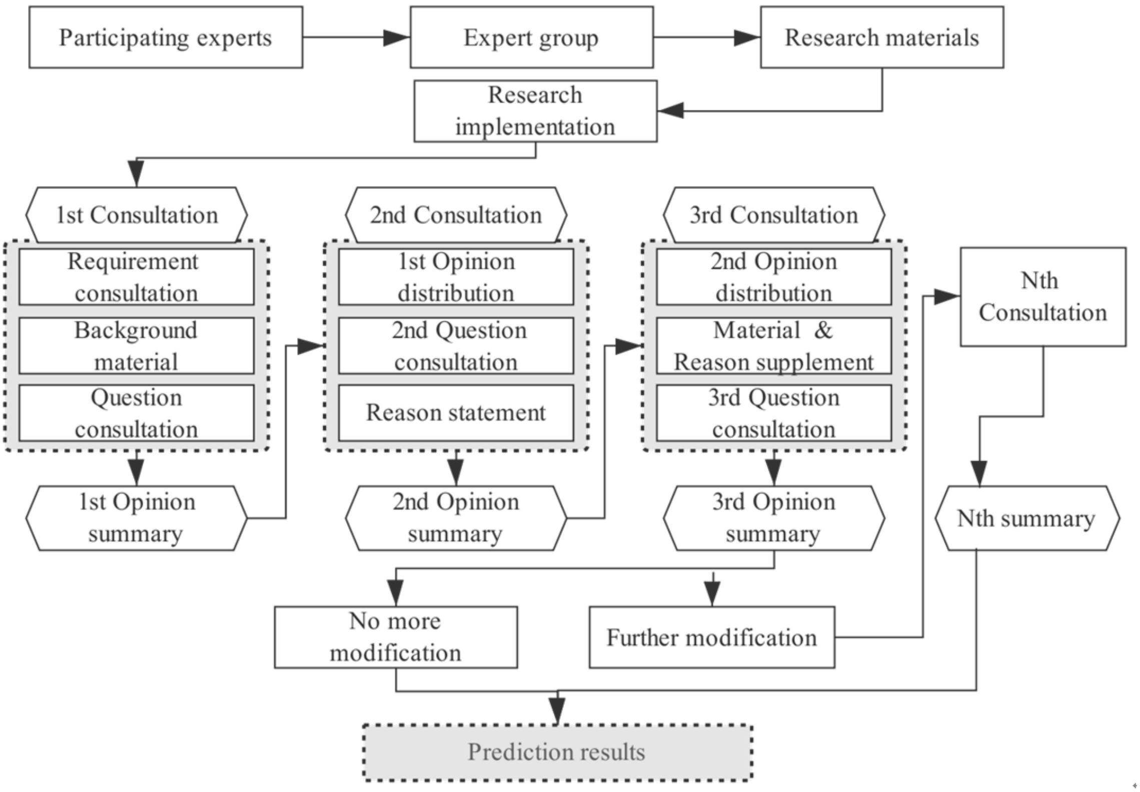


FIGURE 7. The implementation steps of Delphi method

When using utility function as planning objective, it is necessary to determine a set of w_i that reflect the weight of each objective function in the overall objective of the original problem, namely:

$$\max \psi = \sum_{i=1}^{k} w_i \psi_i \tag{3}$$

$$\Phi(x_1, x_2, \ldots, x_n) \le g_i \quad (i = 1, 2, \ldots, m) \tag{4}$$

where w_i should satisfy $\sum_i^k w_i = 1$.

3.4. **Hybrid model and performance evaluation.** Based on the above GRA-Fuzzy logic model of product image design, combined with Delphi method and utility optimization model, the product image design model is further optimized, and then a hybrid model of product image design is constructed as shown in Figure 8.

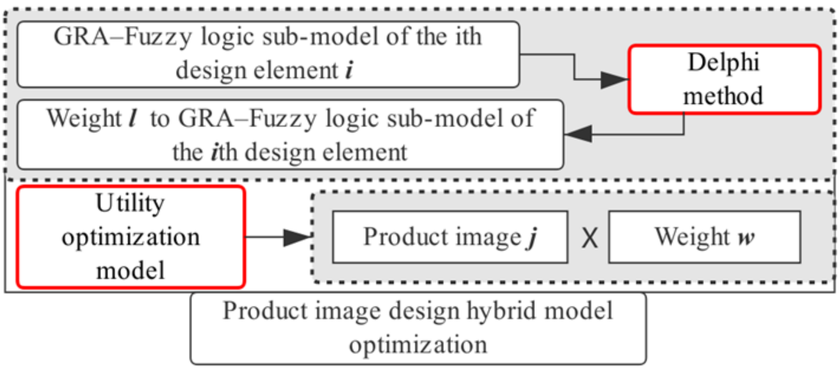


FIGURE 8. Product image design hybrid model optimization

Firstly, the expert group of product design is established for preparing the materials related with train seat design. The design experts are organized to conduct investigation and research, and then obtain the predicted result after N times of consultation and summary. The participating experts analyze the GRA-Fuzzy logic sub-models of product design elements, judge and summarize the weight of each design element affecting product image, provide the corresponding weights of the GRA-Fuzzy logic sub-models of product design elements, and obtain the more accurate product image value. The formula is as follows:

$$f(x) = \sum_{i=1}^{p} l_i f_i(x) \tag{5}$$

$f_i(x)$ represents the GRA-Fuzzy logic sub-model of the product design element i, and l_i is the weight given by the expert group to the GRA-Fuzzy logic sub-model of the ith design element.

Secondly, users generally expect to acquire multiple product images in the process of practical design and production. Utility optimization model is used to transform multi-objective product image into single-objective product total image, which optimizes the GRA-Fuzzy logic model of product design element. Thus weights of product image are obtained according to design objective requirements, which reflects the weight of each product image function in product total image objective, and the total image value of product is obtained by linear weighting method. Finally, the hybrid model of product image design is constructed, namely:

$$g(x) = \sum_{j=1}^{q} w_j g_j(x) \tag{6}$$

$g_j(x)$ is the GRA-Fuzzy logic model of product image j. w_j is the weight of the jth product image function $g_j(x)$ obtained according to the requirements of objective programming in the product total image objective.

In order to evaluate the performance of the hybrid model of product image design, Root Mean Square Error (RMSE) is used as follows [19]:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x_0)^2}{n}} \tag{7}$$

x_i is the ith output value predicted by the hybrid model of product image design, and x_0 is the expected value evaluated by the experimental subjects. We use test samples to evaluate the performance of the hybrid model of product image design. The subjects of second group evaluate the product image of test samples, which get the evaluation value. Then the design elements of each sample are input into the hybrid model of product image design, and the output value of product image is obtained. The performance evaluation of product image design hybrid model is completed by comparing with the assessment results of the subjects. In this paper, to examine the forecasting ability of the hybrid model, we compare its performance with the GRA-Fuzzy logic model as Figure 9.

4. **The Experimental Study of Train Seat Form and Color Image Design.** This section takes the train seat image design as an experimental study. The train seat form image design and color image design based on hybrid model is elaborated from the four primary phases as below.

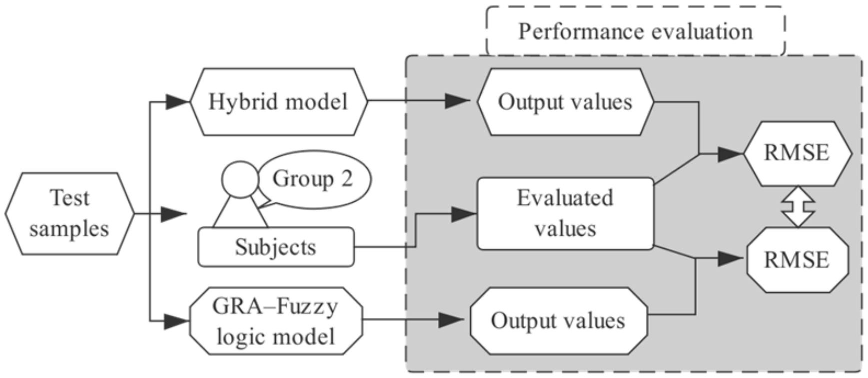


FIGURE 9. The RMSE of the hybrid model and GRA-Fuzzy logic model

4.1. **Kansei engineering experimental process of train seat image design.** The experimental study involves 80 subjects which are divided into four groups. The first and second groups consist of 30 expert users and general users (15 males and 15 females) separately. The third and fourth groups are composed of 10 professional product form and color designers (5 males and 5 females) respectively.

The subjects of first group select the representative seat samples from 186 train seat pictures. Based on the classification results by the first group, we applied the multidimensional scaling analysis and cluster analysis method. Finally, 27 representative train seat samples are obtained to identify and analyze the design elements of train seats.

As the final result of morphological analysis, Table 1 shows the 9 form elements and their corresponding element types extracted from the 27 representative train seat samples. In this study, we select one representative train seat randomly from the 27 representative train seat samples, and fill the selected train seat with 72 representative colors in Figure 10 as the experimental train seat color samples, for a total of 72 color samples. In Table 2, columns 1 and 7 display the numbers of 72 color samples, and the remaining columns display the corresponding color element ("Hue ($h°$)" element (x_{c1}), "Chroma (C^*)" element (x_{c2}), "Lightness (L^*)" element (x_{c3}), "parameter a^*" element (x_{c4}) and "parameter b^*" element (x_{c5})) values of these color samples.

We finally pick out three representative Kansei word pairs for describing the product images of train seats, including Traditional-Modern (T-M), Static-Dynamic (S-D) and Common-Outstanding (C-O). We use the T-M word pair as the primary product image

TABLE 1. Morphological analysis of the form elements on the representative train seat samples

No.	Form design elements	Type 1	Type 2	Type 3	Type 4	Type 5
1	x_1	L	C	A	I	
2	x_2	R	SE	E	I	
3	x_3	I	S	J		
4	x_4	PL	RC	IC		
5	x_5	SL	FL	AL	CL	IL
6	x_6	CF	FF	SF	DF	
7	x_7	SA	PA	CA	LA	
8	x_8	SR	MR	WR		
9	x_9	SA	LA			

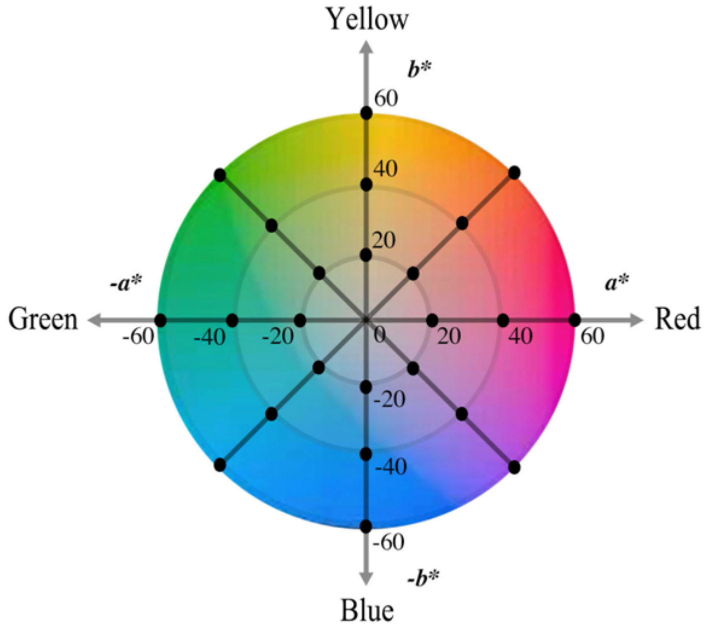


FIGURE 10. (color online) Experimental samples of seat image color design

TABLE 2. Color element values of the representative train seat color sample C10-C21

No.	$h°$	C^*	L^*	a^*	b^*	No.	$h°$	C^*	L^*	a^*	b^*
C10	45	60	30	42	42	C16	45	60	70	42	42
C11	45	40	30	28	28	C17	45	40	70	28	28
C12	45	20	30	14	14	C18	45	20	70	14	14
C13	45	60	50	42	42	C19	90	60	30	0	60
C14	45	40	50	28	28	C20	90	40	30	0	40
C15	45	20	50	14	14	C21	90	20	30	0	20

of train seats to construct the hybrid model of train seat image design. The other two Kansei words are used to evaluate the performance of the hybrid model.

The assessment values for the T-M image of train seats can be obtained by the Likert Seven-Scale questionnaire of the SD method. We ask the 30 subjects of the second group to evaluate the 27 train seat form samples and 72 seat color samples respectively on the corresponding T-M image with a seven-point scale (1-7). The T-M average values, the T-M maximum values and the T-M minimum values of the seat form samples and color samples are obtained, which provide the product image database of train seat form and color samples, for constructing the hybrid model to confirm the numerical value of the T-M image for a given train seat design.

4.2. **GRA-Fuzzy logic model of train seat form and color image design.** Based on the Kansei engineering experiment, the GRA-Fuzzy logic sub-models for the image design of train seat form and color are constructed by using GRA-Fuzzy theory.

The grey correlation coefficients of the form and color design sub-elements are obtained by GRA. The sub-elements of form design affecting the Kansei image of train seat are "Seat-back waistline" (x_5), "Seat-back body shape" (x_4), "Headrest shape" (x_2), "Length ratio between seat-back and seat" (x_8), "Relationship between seat-back and headrest" (x_3) and "Seat-back slope angle" (x_9). The GRA-Fuzzy logic sub-model of the form design sub-elements and Kansei image of the train seat is constructed by using the triangular membership functions, and the corresponding 54 fuzzy rules are constituted. The sub-element which has great influence on the Kansei image of the seat is conducted as the input linguistic variable, and Kansei image of the seat as the output linguistic variable. Then the GRA-Fuzzy logic sub-model of the train seat form image design is constructed.

Similarly, the sub-elements of color design affecting the Kansei image of train seats are "Lightness (L^*)" (x_{c3}), "Chroma (C^*)" (x_{c2}), "parameter a^*" (x_{c4}) and "parameter b^*" (x_{c5}). The GRA-Fuzzy logic sub-model of the color design sub-elements and Kansei image is also constructed by using triangular membership functions. The corresponding 144 fuzzy rules are established, and the GRA-Fuzzy logic sub-model of the train seat color image design is constructed eventually.

4.3. **Hybrid model of train seat form and color image design.** Based on GRA-Fuzzy logic sub-models of high-speed train seat form and color image design in Section 4.2, combined with Delphi method and utility optimization model, the hybrid model of train seat image design is optimized. The hybrid model of train seat form and color image design is divided into the following two stages.

1) Application of Delphi method

According to the knowledge field involved in the train seat, the expert group with relevant product design experience is determined. In this study, 8 product design experts are randomly selected from the expert database, and all relevant information about the image design of high-speed train seat is sent to the 8 experts respectively. Moreover, each expert's opinion is sought to supplement the specific materials needed by each expert.

In terms of the relative information, the experts put forward their own forecast opinions. Delphi method is used to obtain expert's advisory opinions and forecast results. All experts' opinions are collected, summarized and revised. After 3 rounds of discussion, the forecast results of Delphi method are obtained. Each expert makes the percentage evaluation of GRA-Fuzzy logic sub-models which affect the form design and color design of seat image. The final prediction results are as follows. The weight l_1 of GRA-Fuzzy logic sub-model of train seat form design affecting T-M image is 0.36, and the weight l_2 of GRA-Fuzzy logic sub-model of train seat color design affecting T-M image is 0.64.

2) Application of utility optimization model

The utility optimization model is applied for the output value of product image of train seat. Aiming at solving multi-image objective programming, three GRA-Fuzzy logic sub-models of T-M, S-D and C-O images are established respectively. When using utility function as planning objective, three corresponding weights w_1, w_2 and w_3 are used to reflect the weights of GRA-Fuzzy logic sub-models of each Kansei image in the overall objective, and the utility optimization model of the product total image is obtained.

When the users expect the main image of seat design is T-M image, followed by S-D and C-O image. Firstly, combining the online survey, offline questionnaire and user interview, the preliminary results of weights are obtained by using the method of percentage evaluation. After that, the product designers evaluate the survey results, and revise the weight results properly. At last, the product experts and engineers assist in the weight evaluation and verification anonymously, to make sure the reasonability of the determination of weights. According to the above research, the weight w_1 of GRA-Fuzzy logic sub-model reflecting T-M image is 0.4, and the weight w_2 and w_3 of GRA-Fuzzy logic sub-model for S-D image and C-O image are 0.3 respectively. Finally, the total image of multi-image planning objective of train seat design is obtained.

Based on the above experimental process of Kansei engineering, combined with Delphi method and utility optimization model, a hybrid model of high-speed train seat image

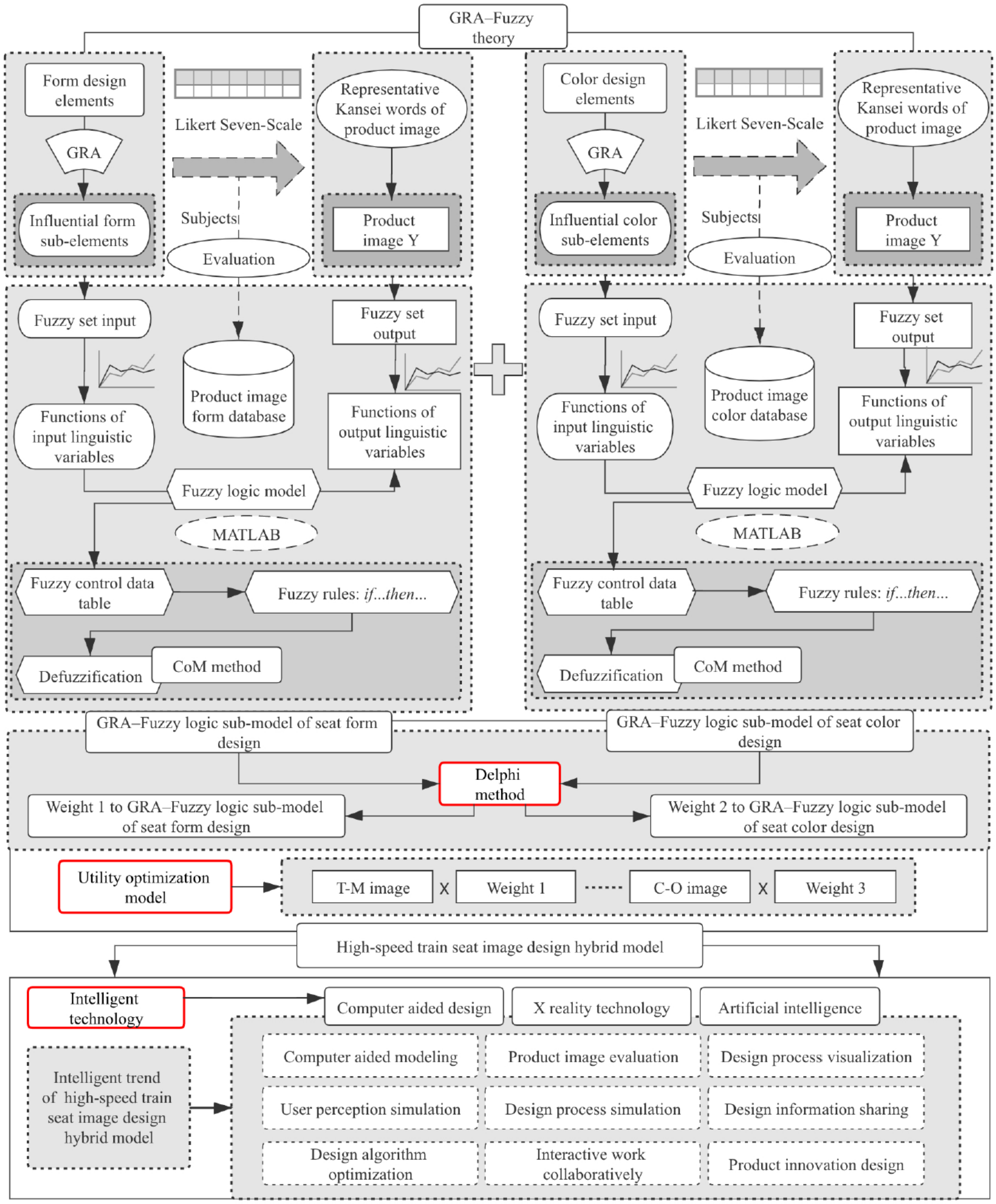


FIGURE 11. High-speed train seat image design hybrid model and intelligent technology trend

design is obtained, and the corresponding trend of intelligent technology is analyzed, as shown in Figure 11. Specifically, the decision-making optimization system of train seat image design based on Kansei engineering is constructed.

4.4. **Performance evaluation of hybrid model.** In order to verify the predictive performance of the hybrid model of train seat image design, the five test samples are used in Table 3. Table 3 shows the sub-elements of form design and color design that have

Table 3. The greater influential sub-elements of form and color design of the test samples

Sample	x_2	x_3	x_4	x_5	x_8	x_9	x_{c2}	x_{c3}	x_{c4}	x_{c5}
1	SE	S	RC	CL	MR	SA	20	30	−14	14
2	I	J	IC	CL	MR	LA	60	70	0	−60
3	E	S	IC	IL	MR	LA	60	30	−42	42
4	I	S	IC	IL	MR	LA	20	70	0	20
5	SE	I	PL	FL	SR	SA	60	50	0	−60

Table 4. RMSE results of the hybrid model and GRA-Fuzzy logic model of train seat image design

T-M value	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	RMSE
Evaluation by subjects	3.60	6.58	5.04	3.80	4.84	
Hybrid model	3.90	6.35	4.31	4.00	4.73	0.3815
GRA-Fuzzy logic model	3.96	6.15	4.24	4.00	4.51	0.4698
S-D value						
Evaluation by subjects	5.05	4.96	5.40	2.32	5.18	
Hybrid model	4.87	4.68	4.85	3.38	4.57	0.6179
GRA-Fuzzy logic model	4.83	4.64	4.82	3.69	4.53	0.7465
C-O value						
Evaluation by subjects	4.22	4.63	2.76	6.02	4.00	
Hybrid model	4.59	5.06	3.60	5.76	4.27	0.4833
GRA-Fuzzy logic model	4.64	5.16	3.92	5.59	4.35	0.6497

greater influence on the product image. Eventually, the performance of the hybrid model of train seat image design is compared with that of the GRA-Fuzzy logic model.

Table 4 shows the average T-M image values of the 30 subjects of second group using seven-point scale to evaluate five test samples, and the T-M values from the hybrid model of seat image design and GRA-Fuzzy logic model respectively. Compared with the T-M image values assessed by 30 subjects in the second row, the final column in Table 4 shows the RMSE values of the above models. The results show that the optimized hybrid model of seat image design has lower RMSE. Therefore, the hybrid model of seat image design is an effective method to match the key elements of seat design with the specific product image.

In product design and production, in order to obtain multi-objective product image, multi-condition fuzzy rules can be used. For example, designers can apply the hybrid model of seat image design and GRA-Fuzzy logic model to inputting the values of seat design elements, and then obtain the values of multiple ideal product images respectively.

In order to further evaluate the performance of the hybrid model and GRA-Fuzzy logic model of seat image design, we choose T-M image as the main image of seat design, followed by S-D and C-O image, and the hybrid model and GRA-Fuzzy logic model of seat image design are built separately to solve the total image of product. The results show that the hybrid model of product image design also has lower RMSE value. Therefore, the hybrid model of seat image design provides an effective mechanism for train seat design to match the total image of product design expected by users.

The good performance of the hybrid model of seat image design shows that the model can help designers to formulate the combination of design sub-elements of high-speed train seats to meet the corresponding Kansei image. Therefore, the optimized hybrid model of product image design provides an effective product design evaluation system. For example, the product designer can input the values of multiple design sub-elements by using the hybrid model of product image design to obtain the predicted values of single-objective or multi-objective product images. If the predicted value does not meet the designers' expectations, the new product image predicted value can be obtained by adjusting the combination of design sub-elements until they obtain the satisfactory product image value.

5. **Research Discussion and Future Work.** The research project involves two limitations. First of all, the subjects' region and the investigation time are limited, and the cognitive differences of the subjects with different age, gender or educational background have different subjective feelings for the product image, so the different subjects can be further classified in the future. In addition, in the aspect of the extension of product research object, the research object of this paper is confined to product form and color. Henceforth research topics can be combined with product materials, product patterns and product environment to analyze and discuss the influence factors of product image.

With the continuous development and application of high technology, intelligent design evaluation has become the future development trend of design industry. CAD, AR, VR and MR technology can promote the use of hybrid model for product image design [20]. For example, Figure 12 illustrates the 3D model and rendering of the train seat sample 2. Computer 3D models of product are built to promote and simulate the image design process.

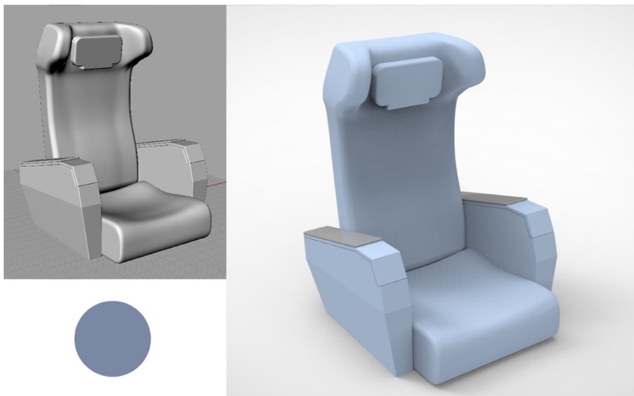


Figure 12. 3D model and rendering of the train seat sample 2

The rapid development of 3D printing technology in digital design and manufacturing improves the accuracy of users' perception of product image, optimizes the efficiency of product design and evaluation, and makes the hybrid model of product Kansei image design more digital, intelligent and systematic. Figure 13 shows the 3D printing drawing of train seat sample 2.

6. **Conclusion.** This paper proposes a hybrid approach of product image design for transforming user's perception into product image design. Based on the analysis of user's Kansei image, a new method that combines GRA, GRA-Fuzzy logic model, Delphi method, utility optimization model and product image design system is developed. Firstly, the GRA-Fuzzy logic model of train seat image form and color design is constructed. Then combining with Delphi method and utility optimization model to optimize product image design system, a hybrid model of product image design is constructed.

To illustrate the approach, an experimental study on train seats is performed based on Kansei engineering theory. The experimental result shows that the hybrid model performs

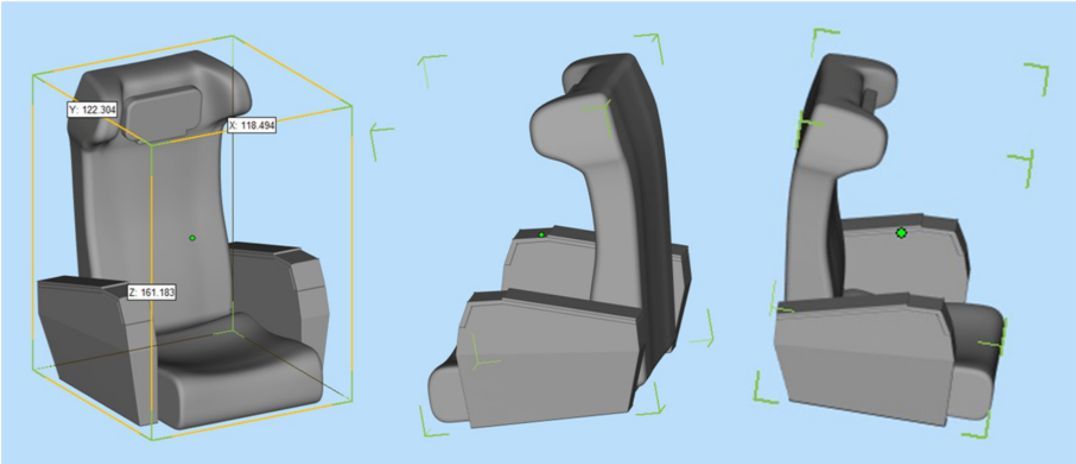


FIGURE 13. 3D printing drawing of train seat sample 2

well in predicting the product image, which is conducive to promoting and optimizing the process of product image design based on user's perception. It provides a new methodological system for product image innovative design and design evaluation, makes up for the weakness of establishing industrial product Kansei image system in existing product design research, and puts forward a more scientific, efficient and intelligent product image design evaluation system.

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